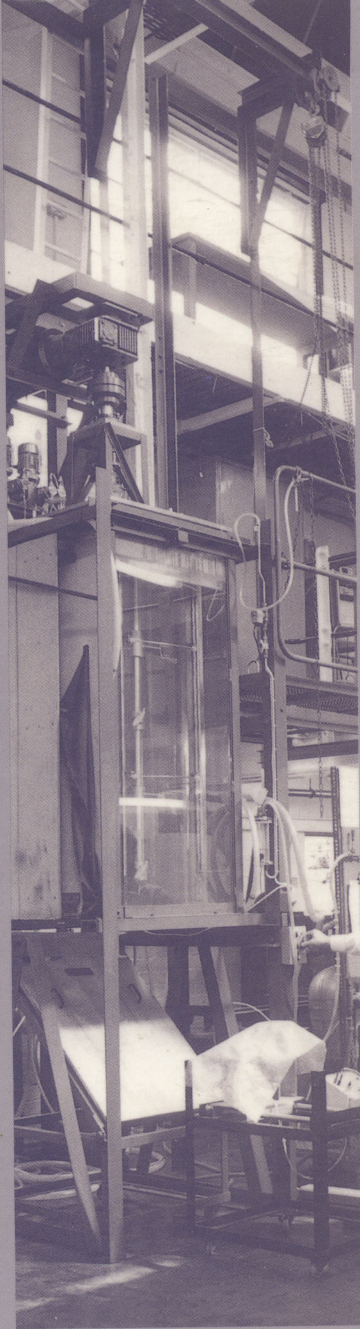
Safety in Chemical Engineering Research and Development



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SAFETY IN CHEMICAL ENGINEERING RESEARCH AND DEVELOPMENT

A guide to safe practices in laboratories and pilot plants

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藏书章

INSTITUTION OF CHEMICAL ENGINEERS

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PREFACE

The purpose of this book is to give advice on a wide range of potential hazards which may be encountered whilst working in chemical engineering departments which are engaged in research and development. It is directed principally at both those who supervise and those who work in such places; in teaching establishments (universities, polytechnics as the like), private companies and other research organisations.

Operations which could be hazardous in a variety of ways may be carried out in small-scale and pilot-plant laboratories and also in workshops, stores and offices. A chemical engineering research facility can be regarded in many ways as a microcosm of a full-scale factory. In the factory processes are carried out on the large scale which in many cases have been developed originally in the chemical engineering laboratory or pilot plant. Accidents which occur in factories are not necessarily directly related to the chemical (or other) process operations themselves. Indeed, experience has shown that many accidents are often quite simple ones such as tripping over obstacles, contact with corrosive chemicals, lifting heavy weights or operating machinery.

In a chemical engineering department all these hazards and many more are a possibility and, for this reason, the scope of this book has deliberately been made wide. In addition to the "traditional" types of accident, information is included on more "sophisticated" hazards, including toxic and flammable substances, noise and vibration, radiation, biological risks and cryogenics. Given such a broad remit, it followed that it would develop into a source-book of information rather than a text-book which attempted to cover virtually every aspect of safety at work in detail, since the production of so comprehensive a document would have resulted in a work extending to many volumes.

The book contains a substantial number of references and a comprehensive bibliography of UK legislation, official and commercial publications, British Standards, etc. It is hoped that, with the help of these, the reader will be able to add detail to those matters of interest to him which he has identified in the text. The references and bibliography represent the best current practice at the time of publication but since at the present time changes in both legislation and technology are proceeding apace, some up-dating will inevitably be needed as time goes on. The general principles given are likely, however, to remain substantially unaltered.

Certain of the Appendices to the book give examples of ways in which formal control should be exercised over particular activities which might be carried on in a chemical engineering department. These include permits-to-work, hot-work permits and the like. It is hoped that their inclusion will help to emphasise to the reader that proper control over these "immediately dangerous" operations (which still, regrettably, continue to cause serious injuries and death) is of the utmost importance. The implementation of a strictly disciplined formal procedure for controlling them is essential.

Where any form of fundamental research (pure or applied) is being carried out, a degree of risk could be introduced by a lack of knowledge of the reactions or processes to be investigated or developed. Emphasis is placed in the book on the essentiality of obtaining as much information as possible about the properties of the materials which are to be used and the conditions under which the process is to be operated. Thus, for example, a runaway exothermic reaction which could result in a dangerous explosion might be avoided or the emission of a highly toxic side-product into the atmosphere be prevented.

Quite obviously, a properly organised and supervised safety regime in a chemical engineering department has, as its first priority, the safety of those who work in the department or who visit it. A second, but equally important objective is that, where the department is part of a teaching establishment, undergraduates and research workers will, as part of their everyday routine, learn how important safety is, in all its aspects. Thus, since many of them will go on to work in industry, it is hoped that the seeds sown during their training will result in a responsible awareness of the importance of safety in its broadest sense throughout their future careers.

There is currently a great deal of public concern about major industrial accidents which could result in danger to the general public or to the environment. Whilst recognising that such a mishap might be possible in relation to the activities in a chemical engineering research and development department, it is not felt that matters such as the effects offsite of a major explosion or toxic gas release are within the remit of this book. Its subject matter, therefore, has been directed principally at ensuring that a high standard of safety exists within the curtilage of the chemical engineering laboratories and their ancillary departments.

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ACKNOWLEDGEMENTS

The guide was compiled by a Working Party of the Engineering Practice Committee of the Institution of Chemical Engineers under the Chairmanship of Dr J.C. Mecklenburgh.

Sadly John Mecklenburgh died in 1986 aged 51. He was a senior lecturer at Nottingham University and a very active member of the Institution. As an internationally known expert in the fields of hazards and chemical plant layout, he was able to contribute greatly to the production of this guide.

The task of editing the draft for the press was undertaken by Mr. C.A. Townsend, Consultant and Dr V.C. Marshall, Bradford University.

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ABBREVIATIONS

ACDP	Advisory Committee on Dangerous Pathogens
ACGM	Advisory Committee on Genetic Manipulation
ANSI	American National Standards Institute
BCF	Bromo-Chloro-Fluoro-Methane
BGC	British Gas Corporation (now British Gas plc)
BOC	British Oxygen Company
BS	British Standard
BSI	British Standards Institution
C Chem	Chartered Chemist
C Eng	Chartered Engineer
CIA	Chemical Industries Association
COSHH	Control of Substances Hazardous to Health
DD	Draft document
DoE	Department of the Environment
DHSS	Department of Health and Social Security
EM	Electromagnetic
FAR	Fatal Accident Rate
HAZOP	Hazard and Operability Study
HMSO	Her Majesty's Stationery Office
HSE	Health and Safety Executive
HSW Act	Health & Safety at Work, etc. Act, 1974
IChemE	Institution of Chemical Engineers
ICI	Imperial Chemical Industries
IGE	Institution of Gas Engineers
LPG	Liquefied Petroleum Gas
LPGITA	The Liquefied Petroleum Gas Industry Technical Association (UK)
ILO	International Labour Office
NIOSH	National Institute for Occupational Safety & Health
R & D	Research and Development
RoSPA	Royal Society for the Prevention of Accidents
RSC	Royal Society of Chemistry
SI	International System of Units (Systeme International d'Unites)
SWL	Safe Working Load
UV	Ultra Violet
wg	Water Gauge

CONTENTS

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1. INTRODUCTION

1.1 TITLE OF THE GUIDE

Though the title of this guide is *Safety in Chemical Engineering Research and Development,* the term safety, unless the context dictates otherwise, should be taken as including occupational health. At the same time certain environmental aspects are also dealt with at the appropriate points.

A 1988 court case highlights the need for a constant awareness of the safety implications in laboratories of all kinds. In the case in question, brought by the HSE, the University of Sussex was fined £2000 with £4000 costs. A post-graduate student was injured when the distillation apparatus he was using exploded; the court found that there was a lack of both instruction and supervision, and that the accepted working procedures were not followed.

1.2 THE NATURE OF THE LABORATORIES COVERED

1.2.1 THE DIFFERENCES BETWEEN CHEMICAL ENGINEERING AND CHEMICAL LABORATORIES

The principal aim of this publication is to provide guidance for those who operate **chemical engineering** as distinct from **chemical** laboratories. Chemical engineering laboratories are used for a variety of purposes. These include research into the characteristics of process equipment, the development of industrial processes for the production of a great variety of products, and the teaching of undergraduate students. Pilot plants, the scale of which lies between that of chemical engineering laboratories and full scale commercial units, may be used both for trials on equipment and for the development of new processes.

Though chemical engineering laboratories which conduct research into the design of equipment are readily distinguishable from chemistry laboratories, it may be more difficult to draw sharp dividing lines where the research is concerned with chemical processes. In this area chemical engineering laboratories may be distinguished from chemical laboratories by the scale of their operations and hence by the scale of the consequences should things go wrong.

To try to put matters into perspective, whereas a chemical laboratory will handle chemical substances in quantities up to, say, about a kilogram, a chemical engineering laboratory may operate up to about 100 kilograms and a pilot plant up to about 1000 kilograms. The scale of size of the equipment will correspond. Whereas in a chemical laboratory a rig will usually have its parts within the reach of the experimenter standing on the ground, ie about 2 metres high, pilot plant rigs may be 15 metres or more in height. The weight of the individual items that make up the rig will also correspond. Whereas most chemical laboratory rigs can be assembled by hand, pilot plants will need cranes or other lifting tackle to assemble or to modify them.

Chemical engineering laboratories and pilot plants are also more likely to incorporate moving machinery and to be more heavily dependent upon services. On the other hand, chemical engineering laboratories and plants will generally use a narrower range of chemicals; these are likely to be handled in bulk and to have less danger of personal contact with those handling them. But the larger the equipment the more difficult it is to enclose it in the way that equipment is contained in a fume cupboard in a chemical laboratory. These special factors are likely to be most pronounced in the case of pilot plants which at their upper end of scale will overlap with full sized production units.

The guide concentrates principally upon those safety aspects of the operation of chemical engineering laboratories and pilot plants which are most distinct from those of chemical laboratories. Those aspects which are common to chemical laboratories are treated in less detail but reference is made to some of the principal publications which do cover the subject in detail.

For similar reasons, the guide does not attempt to treat in a detailed way the principles of engineering workshop practice, even though the laboratories which fall within its scope will usually have such workshops attached to them. Reference is made instead to the relevant literature.

The guide also recognises that some aspects of safety in the laboratories may form part of the safety procedures common to the larger organisation of which the laboratories are a part. Such aspects are referred to but not discussed in detail unless there are special features arising from the nature of the laboratories.

1.2.2 THE BIOCHEMICAL DIMENSION

The recent period has shown a considerable growth in the importance of biochemical engineering and the guide accordingly draws attention to the principal areas of concern. Stress must be laid however upon the need to take expert advice from persons qualified in the appropriate branches of the life sciences.

1.2.3 APPLICATION TO OTHER LABORATORIES

In addition to the mainstream chemical and process engineering laboratories at which the guide is principally aimed, it may be found useful by other laboratories which handle substances rather than develop machinery. Such laboratories may include those concerned with fuels, fire, flame or combustion, especially those in which the character of the work is in a continual state of change with a continuing need to build and modify rigs. Other areas may include the testing of consumer products for safety or other measures of quality.

1.2.4 INDUSTRY AND HIGHER EDUCATION

The intention has been to try to treat the problems of laboratories in higher education and those in industry in an even-handed way but there may be places where this aim has not been entirely achieved. To some extent this arises from having to be mindful of the inevitable presence of students in higher education laboratories. But in industrial laboratories there may be sandwich course or vacation students or other inexperienced trainees to whom the term "student" might reasonably be applied.

The term "university" may be held in this guide to subsume the term "polytechnic".

1.3 A LEGAL UPDATE

1.3.1 THE CIMAH REGULATIONS

Though the *Control of Industrial Major Accident Hazards Regulations (CIMAH) 1984* may be thought of as being concerned only with large scale storage of hazardous materials and that inventories of those materials are measured in tonnes, this is not true. Some thirty substances are listed in Schedule 3 of the Regulations at the level of inventory of 1 kg and there are others at 10 and 100 kg. Laboratory managers are advised to check their stock lists and if they find they have such materials at these levels of inventory in total in their laboratory they should contact the local office of the HSE.

1.3.2 THE COSHH REGULATIONS

The *Control of Substances Hazardous to Health (COSHH) Regulations*, laid before parliament in October 1988, state that an employer must recognise, identify and assess potential health hazards, and should identify the appropriate course of action necessary to minimise the hazard:

- the recognition and assessment of health hazards arising from the handling of substances, including microorganisms;
- measures to monitor and to control exposure to these hazards, where necessary;
- the keeping of records;
- the provision of information, instruction and training to those exposed;
- medical surveillance where special circumstances prevail, especially in certain research situations.

The regulations dictate that it is legally mandatory to demonstrate, if required by the HSE, that employers have assessed any hazards and acted on this assessment; however, there is no legal requirement to follow specific guidelines or working practices.

1.4 THE LAYOUT OF THE GUIDE

It will be noted that the guide is laid out in such a way that there are measures of overlap and possibly repetition between the various sections. This has been deliberate to avoid the need for excessive cross-referencing.

1.5 POSSIBLE APPLICATION ABROAD

Though obviously written in the first place for a British readership it is hoped that the guide may be found useful abroad. The principal barrier lies in the extensive reference to British law but, certainly in the EC, there is taking place a harmonisation of the laws concerning safety, occupational health and the environment. Even outside the EC the principles of safety management set out in the guide still prove useful.

2. THE SAFETY MANAGEMENT OF LABORATORIES

The layout visualised for a typical process research and development (R&D), or teaching complex is a main rig (or pilot plant) area, plus a number of ancillary areas. These could include workshops, analytical laboratories, balance, dark, cold and constant condition rooms, with stores for equipment, chemicals, solvents, cylinders, and services such as steam, water, vacuum, and air. The laboratories will usually be part of a larger site containing building, administrative and emergency services, and in particular a health and safety department.

A management structure assumed in this guide as representative of most R&D organisations is given in Figure 2.1. It is led by the head of laboratory. Each project is headed by a "rig supervisor" who controls a number of investigators. The investigators are assisted by technicians in running, maintaining and building the rigs. The technicians are under the charge of the laboratory superintendent who is responsible for the day-to-day running of the laboratory services and is also responsible for outside staff working in the laboratory. One of the rig supervisors is often the part time departmental safety officer and a typical feature is the collaboration needed between rig supervisors, the safety officer and the laboratory superintendent, as shown by the broken line. In practice structure and job titles may differ according to local circumstances.

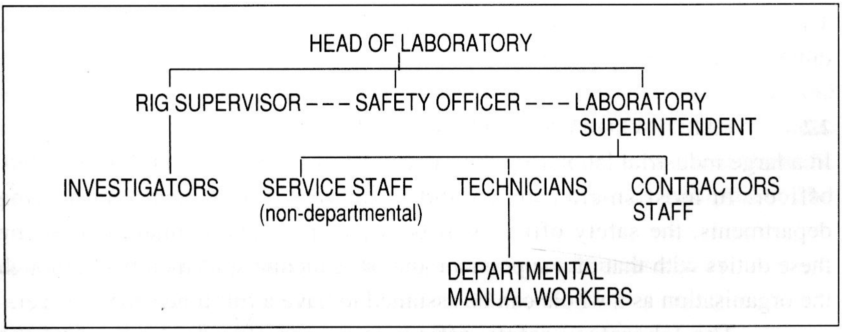

Figure 2.1 A typical management structure for a chemical engineering laboratory

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